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# SEMICONDUCTOR DIODE AND METHOD FOR MANUFACTURING THE SAME

## BACKGROUND OF THE INVENTION

### 1. Field of the invention

This invention relates to a semiconductor diode  
5 having a semiconductor die that includes two opposite  
symmetrical electrodes disposed adjacent to and  
extending along edges of the semiconductor die, and  
to a method for manufacturing the same.

### 2. Description of the related art

10 Light emitting diodes (LED) are wildly used in  
various applications, such as illuminating devices,  
and displays for personal computer and cellular  
phones.

Fig. 1 illustrates a conventional semiconductor  
15 diode 7 which includes a p-electrode metal contact  
71 and an n-electrode metal contact 72 that are  
respectively deposited at two diagonally opposite  
corners of the diode 7. When an electric current  
passes through the p-electrode metal contact 71 and  
20 the n-electrode metal contact 72, an active region  
in the diode 7 emits light that passes through the  
upper surface 73 of the diode 7.

The conventional diode 7 has disadvantages in  
that since the electric current tends to pass through  
25 a shortest distance from the p-electrode metal  
contact 71 to the n-electrode metal contact 72 by  
virtue of a smaller resistance for the shortest

distance, there will be a much higher current density in an area proximate to a diagonal line defined by the two corners and a negligible amount of current in an area that is distal from the diagonal line. As 5 a consequence, the active region in the diode 7 for emitting light is not effectively utilized, thereby resulting in a low light-emitting efficiency for the conventional diode 7.

#### SUMMARY OF THE INVENTION

10 Therefore, the object of the present invention is to provide a semiconductor diode that is capable of overcoming the aforementioned drawbacks.

Another object of the present invention is to provide a method for manufacturing the semiconductor 15 diode of this invention.

According to one aspect of the present invention, there is provided a semiconductor diode comprising a semiconductor die that includes a substrate, a first semiconductor film formed on the substrate, a second semiconductor film formed on the first semiconductor 20 film, a first metal contact formed on the first semiconductor film, and a second metal contact formed on the second semiconductor film. One of the first and second semiconductor films is made of an n-type 25 semiconductor material. The other one of the first and second semiconductor films is made of a p-type semiconductor material. The semiconductor die has two

opposing first side edges and two opposing second side edges which cooperates with the first side edges to define thereamong two diagonally opposite first corners and two diagonally opposite second corners.

- 5 The first semiconductor film has an exposed area that is exposed from the second semiconductor film adjacent to one of the first side edges and that extends between said one of the first corners and one of the second corners. The first metal contact has  
10 a first strip portion that is formed on the exposed area, and a first bonding portion that extends from and that has a width greater than that of the first strip portion and a length less than that of the first strip portion. The second metal contact is disposed  
15 adjacent to the other one of the first side edges and has a second strip portion that extends between the other one of the first corners and the other one of the second corners, and a second bonding portion that extends from and that has a width greater than that  
20 of the second strip portion and a length less than that of the second strip portion.

According to another aspect of the present invention, there is provided a method for manufacturing semiconductor diodes. The method  
25 comprises the steps of: preparing a substrate; forming a first semiconductor film on the substrate; forming a second semiconductor film on the first

semiconductor film, wherein one of the first and second semiconductor films is made of an n-type semiconductor material, and the other one of the first and second semiconductor films is made of a p-type  
5 semiconductor material; selectively masking and etching the second semiconductor film to define a plurality of orderly arranged exposed areas on the first semiconductor film which are exposed from the second semiconductor film; forming a plurality of  
10 orderly arranged first metal contacts on the exposed areas of the first semiconductor film, respectively, and a plurality of second metal contacts on the second semiconductor film, each of the second metal contacts being associated with a respective one of the first  
15 metal contacts; and dicing assembly of the substrate, the first semiconductor film, the second semiconductor film, the first metal contacts, and the second metal contacts to form a plurality of semiconductor dies, each of which has two opposing  
20 first side edges and two opposing second side edges which cooperates with the first side edges to define thereamong two diagonally opposite first corners and two diagonally opposite second corners. The exposed area on the first semiconductor film of each of the  
25 semiconductor dies is disposed adjacent to one of the first side edges and extends between one of the first corners and one of the second corners. The first metal

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contact of each of the semiconductor dies has a first strip portion that is formed on said exposed area, and a first bonding portion that extends from and that has a width greater than that of said first strip portion and a length less than that of said first strip portion. The second metal contact of each of the semiconductor dies is disposed adjacent to the other one of said first side edges and has a second strip portion that extends between the other one of said first corners and the other one of said second corners, and a second bonding portion that extends from and that has a width greater than that of said second strip portion and a length less than that of said second strip portion.

15                   BRIEF DESCRIPTION OF THE DRAWINGS

In drawings which illustrate an embodiment of the invention,

Fig. 1 illustrates a conventional semiconductor diode having two diagonally opposite electrodes;

20                   Fig. 2 illustrates formation of an assembly of an n-type semiconductor film, a quantum well, a p-type semiconductor film, and an ohmic metal contacting film on a substrate according to a method for manufacturing semiconductor diodes embodying this invention;

25                   Fig. 3 illustrates formation of an exposed area on the n-type semiconductor film of the assembly of

Fig. 2 according to the method of this invention;

Figs. 4 and 5 illustrates formation of cutting lines, an n-electrode metal contact, and a p-electrode metal contact on the assembly of Fig. 3

5 according to the method of this invention; and

Fig. 6 illustrates a preferred embodiment of a semiconductor diode formed according to the method of this invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

10       The method for manufacturing semiconductor diodes according to this invention includes the steps of: preparing a substrate; forming a first semiconductor film (preferably an epilayer) on the substrate; forming a second semiconductor film (preferably an epilayer) on the first semiconductor film, wherein one of the first and second semiconductor films is made of an n-type semiconductor material, and the other one of the first and second semiconductor films is made of a p-type  
15       semiconductor material; selectively masking and etching the second semiconductor film to define a plurality of orderly arranged exposed areas on the first semiconductor film which are exposed from the second semiconductor film; forming a plurality of  
20       orderly arranged first metal contacts on the exposed areas of the first semiconductor film, respectively, and a plurality of second metal contacts on the second

semiconductor film, each of the second metal contacts being associated with a respective one of the first metal contacts; and dicing assembly of the substrate, the first semiconductor film, the second semiconductor film, the first metal contacts, and the second metal contacts to form a plurality of semiconductor dies, each of which has two opposing first side edges and two opposing second side edges which cooperates with the first side edges to define thereamong two diagonally opposite first corners and two diagonally opposite second corners. The exposed area on the first semiconductor film of each of the semiconductor dies is disposed adjacent to one of the first side edges and extends between one of the first corners and one of the second corners. The first metal contact of each of the semiconductor dies has a first strip portion that is formed on the exposed area, and a first bonding portion that extends from and that has a width greater than that of the first strip portion and a length less than that of the first strip portion. The second metal contact is disposed adjacent to the other one of the first side edges and has a second strip portion that extends between the other one of the first corners and the other one of the second corners, and a second bonding portion that extends from and that has a width greater than that of the second strip portion and a length less than

100-200-300-400-500-600-700-800-900

that of the second strip portion. The first and second bonding portions can be respectively disposed at arbitrary positions on the first and second strip portions. Preferably, the first bonding portion is  
5 formed on the one of the first corners, the first strip portion extends from the first bonding portion to the one of the second corners, the second bonding portion is formed on the other one of the first corners, and the second strip portion extends from the second  
10 bonding portion to the other one of the second corners.  
15

Figs. 2 to 6 illustrate the consecutive steps for the formation of the semiconductor diodes of this invention in accordance with the preferred embodiment  
15 of the method of this invention.

The processing steps in the preferred embodiment of the method of this invention includes: preparing a substrate 10; forming an n-type semiconductor film 11 on the substrate 10; forming  
20 a quantum well 13 on the n-type semiconductor film 11; forming a p-type semiconductor film 12 on the quantum well 13; forming a thin ohmic metal contacting film 14 on the p-type semiconductor film 12, which can be made from nickel or indium tin oxide (ITO) and  
25 which has a thickness of about 100Å and a transparency of about 90%; selectively masking and etching the ohmic metal contacting film 14, the p-type

semiconductor film 12, the quantum well 13, and an upper portion of the n-type semiconductor film 11 to define a plurality of orderly arranged exposed areas 21 on the n-type semiconductor film 11 which are 5 exposed from the p-type semiconductor film 12 and the metal contacting film 14; selectively masking assembly of the metal contacting film 14, the p-type semiconductor film 12, the quantum well 13, the n-type semiconductor film 11, and the substrate 10 to define 10 a plurality of intersecting first and second cutting lines 31, 32 on the assembly; forming a plurality of orderly arranged n-electrode metal contacts 41 (only one contact is shown) on the exposed areas 21 of the n-type semiconductor film 11, respectively, via vapor deposition of aluminum or titanium by employing photo-masking and lift-off techniques; forming a plurality of orderly arranged dielectric films 61 15 (only one contact is shown) on the metal contacting film 14; selectively forming a plurality of p-electrode metal contacts 51 (only one contact is shown) 20 on the dielectric films 61, respectively, via vapor deposition of aluminum or titanium by employing photo-masking and lift-off techniques; and dicing assembly of the substrate 10, the n-type 25 semiconductor film 11, the quantum well 13, the p-type semiconductor film 12, the metal contacting film 14, the dielectric films 61, the n-electrode metal

contacts 41, and the p-electrode metal contacts 51 along the intersecting first and second cutting lines 31, 32 to form a plurality of semiconductor dies 1, each of which includes one of the n-electrode metal contacts 41 and an associated one of the p-electrode metal contacts 51 and each of which has two parallel first side edges 101 and two parallel second side edges 102 that interconnect the first side edges 101 to define thereamong two diagonally opposite first corners 103 and two diagonally opposite second corners 104.

The exposed area 21 on the n-type semiconductor film 11 of each of the semiconductor dies 1 extends from one of the first corners 103 along one of the first side edges 101 to one of the second corners 104. The n-electrode metal contact 41 of each of the semiconductor dies 1 is formed on and extends along the exposed area 21 from said one of the first corners 103 to said one of the second corners 104. The p-electrode metal contact 51 of each of the semiconductor dies extends from the other one of the first corners 103 along the other one of the first side edges 101 to the other one of the second corners 104. The n-electrode metal contact 41 has a first wire-bonding section 411 disposed at said one of the first corners 103, and an elongated first extension section 412 extending and reducing from the first

wire-bonding section 411 to said one of the second corners 104. Similarly, the p-electrode metal contact 51 has a second wire-bonding section 511 disposed at the other one of the first corners 103, and an elongated second extension section 512 extending and reducing from the second wire-bonding section 511 to the other one of the second corners 104. The second wire-bonding section 511 of each of the p-electrode metal contacts 51 has a geometric dimension greater than that of the respective dielectric film 61, and has a central portion overlapping with the respective dielectric film 61, and a peripheral edge in electrical contact with the metal contacting film 14 so as to prevent electric current from concentrating at the second wire-bonding section 511 and so as to rapidly and evenly distribute the electric current through the second wire-bonding section 511 and the second extension section 512.

The semiconductor dies 1 thus formed are then subjected to wire bonding and packaging with epoxy resin to form semiconductor diodes.

The substrate 10 is preferably made of a material selected from a group consisting of sapphire and silicon carbide. The n-type semiconductor film 11 is preferably made of n-doped GaN (Gallium nitride) material. The p-type semiconductor film 12 is preferably made of p-doped GaN material.

By virtue of extending the n-electrode metal contact 41 from said one of the first corners 103 to said one of the second corners 104 of each semiconductor die 1, and the p-electrode metal contact 51 from the other one of the first corners 103 to the other one of the second corners 104 of each semiconductor die 1, the electric current can be distributed uniformly across the quantum well 13 (see Fig. 6, wherein the broken arrow lines schematically illustrate how electric current is distributed in the semiconductor die 1 of this invention), thereby increasing the light-emitting efficiency of the semiconductor diode of this invention.

With the invention thus explained, it is apparent that various modifications and variations can be made without departing from the spirit of the present invention. It is therefore intended that the invention be limited only as recited in the appended claims.